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Communication Restraints and Mutual Problem-Solving Behavior

A Technical Report and Research Bulletin

prepared by

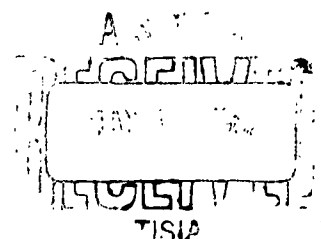
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Educational Testing Service
Princeton, N.J.

April 1962



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MUTUAL PROBLEM-SOLVING BEHAVIOR

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Communication Restraints and Mutual

Problem-Solving Behavior

Abstract

In most situations, communication among parties involved in a group problem-solving situation is regarded as desirable if not essential, since each member's intentions can be made known and future actions made predictable. The present experiment was designed to test the hypothesis that communication facilitates the development of effective and predictable structure-in-interaction and thus contributes to the effectiveness of the group's problem-solving activities.

The subjects, 80 women college graduates ranging in age from 20 to 60 years, were divided into 20 groups of four members each. Ten groups were designated as Communication groups and the remainder as Non-Communication groups. The tasks for all groups were identical: to light a "goal square" in a 5 x 5 electrical plug board in a minimum number of moves. Rules defining permissible moves were imposed to create a mutual task. The Communication groups were permitted to send a written message to any (all) of their partners between trials; the Non-Communication groups were required to send a message to the experimenter at the end of each trial.

Measures relating to task effectiveness and the development of structure-in-interaction were examined. The analysis of each panel of data pointed to the superiority of the Non-Communication groups in both performance and development of structure-in-interaction. This result was not anticipated. Detailed analysis suggests that under certain conditions group task performance may be hindered rather than facilitated by communication.

COMMUNICATION RESTRAINTS AND
MUTUAL PROBLEM-SOLVING BEHAVIOR¹

This is the third in a series of reports on experiments carried out under contract Nonr-2959(00), each with the general purpose of testing a part of a theory about structure-in-interaction and problem solving in group situations.

The first report of the series (Hemphill, 1961) concerned an experiment in which subjects worked with a partner (the experimenter) to perform four simple tasks. The results of this experiment were interpreted as supporting the hypothesis that a structure-in-interaction supplied by another (the experimenter), through consistent responses to the acts of the subjects, was essential to the subjects' ability to work effectively on the tasks.

The second experiment of the series (Hemphill & McConville, 1962) examined the influence of two contrasting experimental sets that were established by representing the subject's "partner" as either another person, "human," or as a mechanical device, "machine." These sets investigated the effects of the characteristics of the partner upon the subject's mutual problem-solving activities. The effects of these two sets were analyzed using measures of (a) the subject's attitudes toward the experiment and toward the behavior of his partner, (b) the subject's over-all effectiveness of work on the tasks, (c) his accuracy of predicting the partner's responses, and (d) patterns of behavior that developed in the sequence of moves on each trial of the tasks. The results of the analyses were generally negative insofar as the effects of "human" vs. "machine" sets were concerned.

In both the first and second experiments each subject interacted with a single partner (the experimenter) who responded in a standard and predetermined manner. In both experiments restraints were imposed upon free

¹Appreciation is expressed to Nathan Kogan and James S. Terwilliger for their comments and review of the manuscript, and to John D. Bowers for assistance in the conduct of the experiment.

communication between the subject and his partner. The instructions for these experiments and the physical arrangements of the laboratory were such that the only possibility of communication between the subject and his partner was that provided by "signaling." Although no such behavior was observed, the subject might have tried to communicate by means of an unusual selection of moves or sequence of moves. However, in non-laboratory situations, communication among parties who are interacting to solve a mutual problem is likely to be a significant factor in the development of structure-in-interaction and is the variable of primary interest in the experiment described in the present report. The general hypothesis under consideration is that communication among parties involved in mutual problem solving facilitates the development of structure-in-interaction which will, in turn, add to the effectiveness of the group's problem-solving activities.

Experimental Procedure

Twenty groups of women of four members each were assembled and scheduled to report at different times to the group laboratory to participate in an experiment concerned with "how groups work together." No attempt was made to match the subjects within groups; a group was formed when four persons could participate at a mutually convenient time. Upon arrival each group member was assigned to a work booth that was separated from others by partitions. The subject was then instructed not to talk during the course of the experiment. Each work booth was equipped with a replica of the plug board described in detail in the previous reports. The four boards were connected with one another, directly square-to-square, in such a manner that the insertion of an "active" plug into a square designated by a letter-number code (e.g., A3, B3, etc.) on one board would cause a neon light to appear in that square on all

four boards. The boards in the four booths were oriented, in respect to one another, in a manner analogous to the situation that would exist if the group members were sitting around the four sides of a single board; i.e., S_1 found square E1 to her upper right, S_2 found E1 to her upper left, S_3 to her lower left, etc. See Figure 1. The relative orientation of each subject's board is stressed here because of its pertinence to a problem that developed in communication.

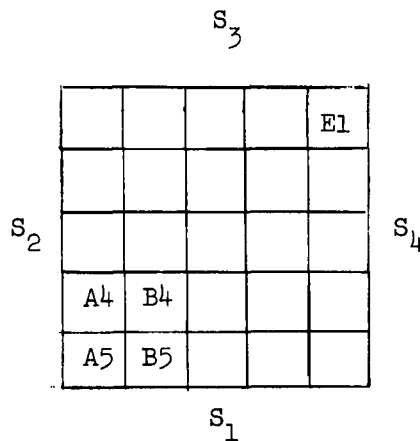


Fig. 1. Layout of each subject's plug board and its position in relation to each of the other three boards.

Each subject was provided four phone plugs, each plug being identified by a different colored tape placed around its body. Each of the four subjects was identified by one of the four colors, and the plug marked with the same color that identified her was made an "active" plug. Her remaining three plugs were "inactive," i.e., did not affect the appearance of the neon lights and were considered to be "marker" plugs. Thus each subject had one active plug of her own color and three "marker" plugs, one for each of the colors identifying her partners.

During the experiment the subjects worked on two tasks. Both tasks were similar and required that the neon light in the "goal" square (E1) be turned on by the insertion of an active plug in that square in a minimum number of moves. The starting positions of the plugs for each trial were the four squares diagonally opposite square E1. The subjects were required to move their active plugs in turn according to a "color" order and to keep track of the moves of the other subjects by the use of their marker plugs. The selection of the subject who was asked to make the first move on a trial was varied systematically from trial to trial as was the color arrangement of the four plugs in the four starting squares. Subjects were allowed seven moves on each trial to achieve the goal in Task I; the minimum number of moves was five. In Task II, the goal square could be reached in six, seven, or eight moves depending on the starting order of the plugs; the subjects were allowed 10 moves per trial. Up to 16 trials per task were provided if the criterion of four perfect trials in succession was not achieved sooner.

Task II always followed Task I and differed from this first task only by a change in the rules governing what constituted a legal move. Under the conditions of Task I, moves could be made to any square adjacent to one occupied by another plug. Diagonal adjacencies were permitted. The rules governing Task II did not allow moves to diagonally adjacent squares. This, of course, complicated the task perhaps more than might be expected by such a simple change in rules. (The complete instructions to the subjects are given in Appendix A.)

Ten of the 20 groups were designated as Communication groups, the remaining 10 as Non-Communication groups. The subjects in the Communication groups were provided one minute immediately after each trial to prepare a

10-word (or less) message to any one or all of the three other subjects in the group. The messages then were collected by the experimenter and quickly distributed to the addressees, who had the remainder of an additional minute to read whatever messages each had received. No restrictions were placed on the contents of the messages, and the subjects were free to send or not to send a message to any of their partners.

In order to provide comparable tasks for the Non-Communication groups between trials, each of these subjects was asked to prepare a note to the experimenter stating the solution of the problem her group faced, or if she had no solution to so state that fact in her note. She was given one and a half minutes to study the problem and prepare the note. It was estimated that approximately one-half minute was consumed in the distribution of the messages in the Communication groups, which accounts for the one and one-half minutes used by the Non-Communication groups instead of the full two minutes.

At the end of the experiment, an additional trial on Task II was provided but with the instructions requiring that each subject write down her prediction of the move to follow just before it was made. This post-experimental exercise was considered a test of each group member's understanding of the structure-in-interaction that may have developed in the group as a result of their work together on the tasks.

Subjects

The 80 subjects who participated in the experiment were women whose ages varied from 20 to 60 years. They were recruited for the experiment by contacts with local women's organizations. Each was compensated for her participation by being able to donate her earnings to the treasury of her organization.

Thus the subjects were moderately well acquainted with one another and relatively homogeneous in interest and background. Most had completed college, and in the experimenters' judgment, all could be described as well above average in general intelligence.

Experimental Data

The subjects were observed by means of one-way vision mirrors as they worked on the task, and a careful record was maintained of the moves selected by each subject on each trial. The messages written by the subject to her partners were collected between each trial, furnishing information about the progress of the subject toward solution of the tasks. The notes to the experimenter from the Non-Communication subjects served the same purpose. The data provided by the post-experimental prediction exercise were also available for analysis. Each of these panels of data will be examined in the following section of this report to determine how the condition of Communication or Non-Communication may have influenced the development of structure-in-interaction.

Task Performance

The effectiveness of task performance was examined with respect to two related criteria of effectiveness.

Criterion A. The first criterion of effectiveness was the number of trials required to reach four successive errorless solutions of the tasks. This criterion was selected because four such solutions could be attained only if each member of the four-person group made a correct first move. It was necessary, of course, that all the remaining required moves be made without error, but the first move was a critical one. If four consecutive

errorless trials were completed, it was assumed that the group had learned to perform the task. Since up to 16 trials were allowed for each task, scores might range from 4 to 20. These scores, 17, 18, 19, and 20, are reasonable ones to assign in the event that an error was made on the thirteenth through sixteenth trials respectively since, had the opportunity been provided, at least this number of trials would have been required to reach the criterion. Table 1 shows the performance of each of the 20 teams as measured by this criterion.

The data show clearly that the groups in which communication was permitted did not reach the criterion in fewer trials than did the groups in which there was no communication between group members. In fact, the difference for both tasks favor the Non-Communication groups. Tests of the significance of this unanticipated result were made by partitioning chi-square and then comparing the Within Conditions (Communication vs. Non-Communication) component with the Between Conditions component. The results of these tests are shown in Table 2.

At least for Task I it is necessary to conclude that the Non-Communication condition produced the more effective task performance. For Task II the observed differences are in the same direction but not clearly significant.

Criterion B. The second criterion of task effectiveness was based upon a concept of moves remaining similar to that employed in the previous report (Hemphill & McConville, 1962). On many trials the goal square was not reached within the minimum number of moves. Moves remaining refers to the distance between the goal and the nearest square to the goal which was occupied after the minimum number of moves on a trial had been made. This distance was measured in terms of the number of moves that would be required

Table 1

Effectiveness of Task Performance of 20 Groups as Measured
by "Number of Trials to Criterion"
(Criterion A)

Communication Groups			Non-Communication Groups		
Group	Task I	Task II	Group	Task I	Task II
1	10	18	11	8	17
2	8	19	12	13	17
3	17	12	13	7	13
4	18	20	14	10	14
5	9	15	15	12	15
6	17	12	16	6	20
7	20	19	17	13	7
8	8	20	18	7	5
9	10	20	19	9	11
10	8	20	20	9	10
Mean	12.5	17.5	Mean	9.4	12.9

Table 2

Partitions of Chi-Square Testing the Effects of Conditions of
Communication Upon the Effectiveness of
Performance on Two Tasks

Task	Source	χ^2	df	Mean Square	F	Sig.
I	Between Conditions	166.72	1	166.72	9.27	<.01
	Within Conditions	323.63	18	17.98		
	Total	490.35	19			
II	Between Conditions	60.37	1	60.37	3.79	<.10
	Within Conditions	286.68	18	15.93		
	Total		19			

to cover the remaining distance to the goal. The count of moves remaining was made with the observation of the same rules specifying a "legal" move that were in force for the task; i.e., for Task I diagonal moves were permissible and the distance measure was of the usual Euclidean type, but in Task II, for which diagonal moves were not permitted, the distance measure was of the "city block" variety.

Two moves remaining scores were obtained for each task. The first was the sum of moves remaining for the first four trials made by the group on the task. The score is indicative of the degree of early progress the group made on the task. The second sum of moves remaining was for the last four trials on the task, numbers 13, 14, 15, and 16 for groups who failed to reach the criterion of four perfect trials. For groups who had reached the criterion, the score would, of course, be zero; since, if the last four trials were performed without error, no moves could remain to be counted. This second measure was indicative of a group's continued difficulty in solving the problem of the task. Table 3 presents the score for each group on these Criterion B scores.

The data presented in Table 3 are consistent with the data for Criterion A (Table 1) for each comparison. Non-Communication groups appear to be more effective both on the earlier and later trials and on both Tasks I and II. All 10 of the groups who worked under the Non-Communication condition were able to reach the goal square for Task I in seven, or less, moves in a maximum of 12 trials; seven of the 10 groups were able to do so on Task II. This can be compared with the record for the Communication groups where it was found that four groups still were having difficulty with Task I after 12 trials, and only three groups had solved Task II in 12 trials.

Table 3

Effectiveness of Task Performance of 20 Groups as
Measured by "Number of Moves Remaining"
(Criterion B)

Communication Groups					Non-Communication Groups				
Group	Task I		Task II		Group	Task I		Task II	
	First	Last	First	Last		First	Last	First	Last
1	10	0	17	4	11	6	0	6	2
2	9	0	7	6	12	4	0	2	3
3	7	1	8	0	13	7	0	9	0
4	7	2	10	9	14	4	0	12	0
5	6	0	4	0	15	9	0	8	0
6	8	4	13	0	16	5	0	17	11
7	8	7	13	4	17	9	0	5	0
8	8	0	12	8	18	5	0	2	0
9	10	0	12	11	19	10	0	11	0
10	8	0	16	5	20	6	0	12	0
Mean	8.1	1.4	11.2	4.7	Mean	6.5	0	8.4	1.6

Table 4 shows the results of tests of significance for these findings for Criterion B.

No one of these tests yielded results significant at the .05 level of confidence; however, all four tests reached the .10 level and, as noted before, the trend is in favor of the Non-Communication groups. It seems clear that one can conclude that the 10 groups who were permitted to communicate between trials did no better on the tasks than the groups who simply prepared a note for the experimenter about how the problem might be solved.

The contents of the notes prepared between trials by both the Communication and the Non-Communication groups were then examined in detail in an effort to account for this result.

Problem Analysis

The messages that were prepared by the subjects were examined by noting whether they contained any of the following contents:

1. Mention of patterns, path, route, etc. that should or might be used in reaching the goal square. (Paths)
2. Mention of order or sequence of moves that should or might be used. (Order)
3. Mention of blocking, a need to wait on others, or interfering with the moves that need to be made by others. (Blocks)
4. Mention of a general principle or over-all strategy for solution of the problem. (Principle)
5. Mention of a specific move that should or should not be made. (Specific)

Table 4

Partition of Chi-Square Testing the Effects of Conditions of
Communication Upon Effectiveness of Performance
(Criterion B)

Task	Trials	Source	χ^2	df	Mean Square	F	Sig.
I	First	Between Conditions	1.753	1	1.75	3.98	<.10
		Within Conditions	7.863	18	.44		
		Total	9.616				
I	Last	Between Conditions	14.00	1	14.00	3.50	<.10
		Within Conditions	72.00	18	4.00		
		Total	86.00				
II	First	Between Conditions	4.00	1	4.00	2.01	<.10
		Within Conditions	35.92	18	1.99		
		Total	39.92				
II	Last	Between Conditions	15.25	1	15.25	3.50	<.10
		Within Conditions	78.25	18	4.35		
		Total	93.50				

6. Mention of a totally incorrect move, route, or procedure which if followed could not possibly lead to goal attainment. (Incorrect)
7. Use of literal, as contrasted with symbolic, concept in describing the problem, i.e., "down," "across," "right," "left," "over," etc. rather than the letter-number codes of squares, such as A3, B5, C4, etc. (Literal)

The classification of message contents with respect to each of these seven categories was done independently by two assistants. A message was examined for all seven categories and scored for each category it contained. Agreement between judges was satisfactory as is shown in Table 5 by the proportion of all messages that were classified in the same manner by both judges.

A contents-of-communications score was computed for each of the seven categories. These scores are based upon the number of opportunities to communicate that were available to the group, since groups who had quickly reached the criterion of four perfect trials did not have the same number of opportunities as those who ran the complete series of 16 trials per task. Each group member was considered to have one opportunity to communicate during each trial; thus a group that used the entire 16 trials had 64 opportunities to communicate. The category score is the proportion of these opportunities in which the message(s) included the various contents. The two assistants' classifications of contents were averaged in the process of obtaining these scores.

Contents scores were obtained for each individual, whether they were run under the Communication or under the Non-Communication condition. (It will be recalled that Non-Communication subjects wrote their messages to

Table 5

Proportion of Individual Categories Scored in the
Same Manner by Two Independent Judges

Contents Category	Task I Proportion of Messages	Task II Proportion of Messages
Paths	.92	.89
Order	.84	.75
Blocks	.91	.91
Principle	.89	.86
Specific	.96	.96
Incorrect	.92	.89
Literal	.97	.96

the experimenter.) Table 6 shows the number of opportunities to communicate that were used. Under the Non-Communication condition, the subjects were required to hand a note to the experimenter at the end of each trial; but when those messages simply stated that the subject had "no solution," they were considered as equivalent to not sending a message by the subjects under the Communication condition.

It is apparent that the Non-Communication group members had, or believed they had, a solution to the problem more frequently than the Communication group members chose to communicate a possible solution, if they had one. At least a part of this difference in utilization of opportunity to communicate may be attributed to the differences in the directions for sending messages that were given to the subjects run under the two conditions. These directions were as follows:

For the Communication groups:

"To help you in this task, you will be allowed to send a short message of 10 words or less to as many of the other members of the group as you wish, that is, up to three separate messages. You will have one minute at the end of each trial to write your messages, at which time they will be collected and delivered to the person or persons to whom they are addressed. The person who receives a message will have one minute to read the message before they are collected again. You should address your message to the color denoting the person to whom you wish to communicate and sign it with your own color. There is no limitation as to contents, but remember you must make your message 10 words or less. You do not have to send a message, but you will lose nothing if you do so."

Table 6

Proportion of Opportunities to Communicate Utilized
under Communication and Non-Communication
Conditions for Tasks I and II

Communication Groups			Non-Communication Groups		
Group	Task I	Task II	Group	Task I	Task II
1	.15	.17	11	.88	.64
2	.19	.17	12	.83	.91
3	.11	.08	13	.89	.75
4	.23	.05	14	.90	.82
5	.14	.15	15	.62	.32
6	.03	.00	16	.83	.72
7	.03	.05	17	.85	.68
8	.16	.11	18	.75	.85
9	.38	.58	19	.67	.61
10	.00	.09	20	.78	.82
Mean	.14	.14	Mean	.80	.71

For the Non-Communication groups:

"To help you in this task you will be allowed a period of one minute at the end of each trial to examine the problem. At the end of this time you will be required to write a short note to me. If you have discovered the answer you should jot down the five moves required for the solution of the task. If you have not as yet discovered the solution, write 'no solution' on your note and pass this in. Each of you should sign these notes with your color."

The directions may have focused the attention of the Non-Communication subjects more squarely upon the analysis of the problem faced by the group. The directions and the situations within which they were given also would tend to prompt the Non-Communication subjects to offer solutions even if they were tentative ones; but perhaps the Communication subjects, influenced by the possibility of negative reactions from their fellow group members, waited until they were relatively sure of the solution before suggesting it to the others.

The category scores for the seven contents areas are given in Table 7.

For each of the seven categories of contents, the data in Table 7 show a higher utilization by the groups run under the Non-Communication condition than by the other groups. The two larger of these differences (for the categories Paths and Specific) perhaps can be best attributed to that part of the directions given to the Non-Communication groups as follows: ". . . you should jot down the five moves required for the solution of the task."

The following responses would have been classified in both the Paths and Specific contents categories:

a. A3
B4
C2
E2
E1

b. A3, B2, C1, D1, E1

These same responses, if they appeared in the messages prepared by subjects run under the Communication condition, also would have been scored for both categories, but the directions suggest some form of listing a series of responses only in the case of the Non-Communication condition. This may be responsible for at least a portion of the large differences that are observed.

In the case of the categories Order, Block, and Principle, it is difficult to find an explanation for their greater frequency of utilization in the difference between instructions given under the two conditions. In neither case was there any suggestion given of order or sequence, of blocking, waiting, etc., or of a general principle which might be involved in the task's solution. Yet the Non-Communication subjects used concepts of orders about twice as often as the Communication subjects and of blocking about 10 times as frequently, and they stated a general principle for solving the problem about five times as often. It seems that explanations of these differences require some general change in set toward the group's problem which would be consistent with a tendency for the Non-Communication subjects to apply more effort to the analysis of the task. This would be consistent with the observation that although the Non-Communication subjects more frequently stated a principle by which the task might be solved, they also gave about four times as many incorrect responses as did the Communication groups.

The data presented in Table 7 were based on the absolute frequency with which the content described by each of the seven categories was noted in the communications. Table 8 presents the same frequencies in relative terms, since from Table 6 it is clear that a major difference between Communication and Non-Communication groups was simply the frequency with which opportunities to send messages were utilized. The proportions in Table 8 are based upon the number of opportunities to send messages that were actually utilized rather than the absolute number that were available.

Table 7
Task Analysis of Proportion of Opportunities Used to
Mention Each of Seven Categories of Contents.

Group	Task I														
	Paths		Order		Blocks		Principle		Specific		Incorrect		Literal		
Com.	Non-Com.	Com.	Non-Com.	Com.	Non-Com.	Com.	Non-Com.	Com.	Non-Com.	Com.	Non-Com.	Com.	Non-Com.	Com.	Non-Com.
1	.11	.06	.88	.05	.00	.01	.05	.01	.02	.15	.88	.06	.12	.00	.00
2	.12	.11	.58	.05	.17	.00	.10	.00	.20	.16	.76	.16	.10	.00	.00
3	.13	.01	.61	.04	.07	.01	.20	.02	.18	.08	.68	.07	.21	.01	.00
4	.14	.01	.82	.02	.08	.02	.02	.06	.06	.05	.82	.01	.11	.02	.05
5	.15	.00	.50	.01	.06	.01	.31	.03	.09	.14	.52	.00	.22	.00	.00
6	.16	.00	.79	.01	.00	.00	.00	.01	.00	.02	.79	.01	.10	.00	.00
7	.17	.00	.59	.01	.20	.00	.06	.00	.13	.02	.63	.01	.25	.01	.03
8	.18	.12	.75	.03	.00	.00	.12	.00	.00	.14	.78	.09	.21	.00	.00
9	.19	.08	.42	.10	.11	.06	.46	.04	.17	.20	.47	.02	.17	.00	.01
10	.20	.00	.32	.00	.15	.00	.11	.00	.38	.00	.29	.00	.18	.00	.04
Mean		.039	.646	.032	.085	.011	.143	.017	.125	.096	.664	.043	.169	.04	.013

Table 7 (Continued)

Group	Task II													
	Paths		Order		Blocks		Principle		Specific		Incorrect		Literal	
Com.	Com.	Non-Com.	Com.	Non-Com.	Com.	Non-Com.	Com.	Non-Com.	Com.	Non-Com.	Com.	Non-Com.	Com.	Non-Com.
1	.03	.63	.06	.01	.05	.26	.08	.02	.05	.62	.01	.08	.08	.00
2	.09	.46	.07	.23	.01	.37	.04	.33	.12	.64	.04	.03	.05	.18
3	.01	.56	.05	.09	.00	.18	.03	.18	.04	.56	.00	.21	.00	.00
4	.00	.66	.02	.10	.01	.41	.03	.12	.00	.73	.00	.10	.00	.01
5	.01	.03	.06	.13	.05	.07	.03	.28	.10	.03	.01	.03	.00	.01
6	.00	.58	.00	.06	.00	.24	.00	.07	.00	.59	.00	.12	.00	.02
7	.01	.38	.00	.12	.01	.20	.02	.32	.00	.36	.00	.20	.04	.09
8	.08	.75	.02	.02	.02	.30	.02	.10	.08	.75	.01	.12	.03	.00
9	.11	.28	.20	.15	.08	.02	.18	.22	.09	.33	.06	.18	.12	.02
10	.01	.36	.04	.12	.03	.11	.04	.38	.02	.38	.01	.15	.03	.16
Mean	.034	.469	.052	.100	.026	.216	.044	.202	.050	.499	.014	.122	.035	.065

Table 8 shows that relative to other content in their messages the Communication subjects emphasized the order in which moves were to be made more often than did the Non-Communication subjects. They also appear to have used literal language in the messages a greater part of the time than the Non-Communication subjects. However, even in terms of relative emphasis the Non-Communication subjects' messages can be characterized by their emphasizing Paths, Blocks, and Specific moves. Differences in frequency of discovery of the general principle or in statements of incorrect solutions, as discussed previously, in connection with Table 7, appear to be almost entirely a function of the larger number of messages prepared by the Non-Communication subjects.

Groups run under the Communication condition utilized a significant proportion of their messages for purposes other than sharing the results of their analysis of the tasks. Data shown in Table 9 summarize an examination of the contents of messages sent within the 10 Communication groups from a point of view of group-process variables.

Only the group-process variable "Giving Information" corresponds in a general way with the purpose of the messages prepared by the Non-Communication groups, i.e., the Non-Communication subjects prepared their messages to give information to the experimenters. Thus, the period between trials appears to have served different ends for the Communication subjects than for the Non-Communication subjects. In the Communication groups, a significant proportion of the time available seems to have been used in efforts to solve problems related to a concern with the other group members' behavior, i.e., to attempt to lead or to express sentiment. Concentration upon the group-process areas of giving or asking for information which characterizes

Table 8

Task Analysis of Relative Proportion of Opportunities Used to Mention Each of Seven Categories of Contents

Group	Task I														
	Paths		Order		Blocks		Principle		Specific		Incorrect		Literal		
Com.	Non-Com.	Com.	Non-Com.	Com.	Non-Com.	Com.	Non-Com.	Com.	Non-Com.	Com.	Non-Com.	Com.	Non-Com.		
1	11	.42	1.00	.33	.00	.08	.05	.08	.02	1.00	1.00	.42	.14	.00	.00
2	12	.58	.70	.25	.21	.00	.13	.00	.24	.83	.92	.83	.13	.00	.00
3	13	.07	.68	.36	.08	.07	.22	.14	.20	.79	.76	.64	.24	.07	.00
4	14	.03	.92	.10	.08	.07	.03	.27	.07	.20	.92	.03	.12	.07	.06
5	15	.00	.80	.10	.10	.10	.50	.20	.15	1.00	.83	.00	.35	.00	.00
6	16	.00	.76	.25	.00	.00	.00	.25	.00	.50	.76	.25	.10	.00	.00
7	17	.00	.69	.25	.24	.00	.07	.00	.16	.75	.75	.25	.30	.25	.03
8	18	.80	1.00	.20	.00	.00	.17	.00	.00	.90	1.00	.60	.29	.00	.00
9	19	.20	.62	.27	.17	.17	.69	.10	.25	.53	.71	.07	.25	.00	.02
10	20	.00	.41	.00	.20	.00	.14	.00	.48	.00	.38	.00	.23	.00	.05
Mean		.210	.758	.211	.108	.049	.200	.104	.157	.650	.803	.289	.205	.039	.016

Table 8 (Continued)

Group	Task II														
	Paths		Order		Blocks		Principle		Specific		Incorrect		Literal		
Com.	Non-Com.	Com.	Non-Com.	Com.	Non-Com.	Com.	Non-Com.	Com.	Non-Com.	Com.	Non-Com.	Com.	Non-Com.	Com.	Non-Com.
1	.11	.18	.99	.36	.01	.27	.40	.45	.02	.27	.98	.05	.13	.45	.00
2	.12	.55	.51	.41	.25	.05	.41	.23	.36	.73	.71	.23	.03	.32	.20
3	.13	.12	.74	.62	.12	.00	.24	.38	.24	.50	.74	.00	.28	.00	.00
4	.14	.00	.80	.50	.12	.17	.50	.67	.15	.00	.89	.00	.12	.00	.01
5	.15	.06	.08	.39	.42	.33	.21	.22	.87	.67	.11	.06	.11	.00	.03
6	.16	.00	.80	.00	.09	.00	.34	.00	.10	.00	.83	.00	.16	.00	.02
7	.17	.17	.55	.00	.18	.17	.29	.50	.47	.00	.53	.00	.29	.83	.13
8	.18	.71	.88	.14	.03	.21	.35	.21	.12	.71	.88	.07	.15	.29	.00
9	.19	.19	.46	.34	.24	.14	.04	.31	.35	.16	.54	.11	.30	.22	.04
10	.20	.08	.44	.42	.15	.33	.14	.42	.45	.25	.45	.00	.18	.33	.20
Mean		.205	.625	.318	.161	.166	.292	.339	.313	.329	.666	.052	.175	.244	.063

Table 9

Non-Task Analysis of Contents of Messages Sent
by 40 Communication Subjects

Category	Task I		Task II	
	Number	Proportion	Number	Proportion
Leading	151	.40	358	.73
Giving Information	136	.36	285	.58
Asking for Information	41	.11	14	.03
Expressing Sentiment	42	.11	40	.08
Out of Field	11	.03	4	.01

activities more directly related to analysis of the problem may have been diverted by the possibilities of influencing the work of associates.

In summary, the analysis of the notes or messages that were prepared between trials suggests a major difference between the Communication and Non-Communication conditions. It can be assumed that Non-Communication groups focused their attention upon the analysis of the task, perhaps because it was impossible for them to influence the behavior of other group members by sending a note to the experimenter.

Since the Non-Communication groups performed the task in a superior manner, it appears either that correct analysis of the task was a key factor to effective performance and/or that inefficiencies in group processes (e.g., leading and exchanging information) outweighed the expected advantage of the group members' being permitted to communicate. In order to provide some basis for choosing between these two possibilities, an examination was made of the messages sent under the Communication condition to determine the effect on the "trials to criterion" score, assuming that group process had been efficient, i.e., if the first group member who had found a correct solution had then communicated it effectively to achieve a correct performance of the task by his associates from that point on. This examination disclosed that the scores reported in Table 1 would have remained unchanged. In fact none of the 40 Communication subjects had attempted to communicate a totally correct solution to the problems of Task II, and only five did so for the simple problem of Task I. However, four subjects under the Non-Communication condition reported generally correct solutions to Task II, and 15 did so for Task I. It would appear that the opportunity to communicate with one another functioned as a distraction rather than as a facilitation of effective work by groups on these tasks.

Post-Experimental Predictions

It will be recalled that after the groups had completed work on Task II they were asked to run through this task again, but that before each move was made each group member indicated to which square they would move. For three of the four subjects this required a prediction, but for the fourth it was, of course, merely an indication of an intention. Without exception, the subject making the move did as he had indicated he would. The accuracy of the group's prediction can be considered as a measure of how well each person had learned what to expect of his associates and as an indication of the degree of structure-in-interaction that the group had developed. Correct predictions could be of two kinds: (a) predictions that were not only correct in the sense that they corresponded with what happened on the next move, but also correct in the sense that the move would bring the group nearer a solution of the problem, and (b) predictions that were correct only in that they forecasted the move that was actually made. It is also possible to observe two types of incorrect predictions of moves: (a) moves which if they had been made would have contributed to the effective performance, and, of course, (b) incorrect predictions of moves that also would have been ineffective, i.e., totally incorrect predictions. Table 10 summarizes the prediction data.

The fact that the Communication groups were slightly inferior in the effectiveness with which they performed the task is indicated by the larger number of predictions they were required to make, because they less frequently solved the problem in less than the maximum number of moves allowed. (The Communication group used 8.8 moves on the average as compared with 8.3 for the Non-Communication groups.) Thus, the relationship between effectiveness

Table 10

Performance of Communication and Non-Communication Groups on the Post-Experimental Exercise

Group	No Pred.	Communication						Non-Communication					
		Correct Prediction			Incorrect Prediction			Correct Prediction			Incorrect Prediction		
		Effective	Ineffective		Effective	Ineffective		Effective	Ineffective		Effective	Ineffective	
			No.	%		No.	%		No.	%		No.	%
1	30	8	27	11	37	2	7	9	30	12	50	2	8
2	30	5	17	17	57	4	13	4	13	13	62	0	0
3	30	12	40	6	20	7	23	5	17	9	30	8	27
4	27	11	41	4	15	2	7	10	37	9	30	10	33
5	24	10	42	0	0	14	58	0	0	16	76	0	0
6	21	11	52	0	0	5	24	5	24	14	67	0	0
7	30	9	30	8	27	5	17	8	27	4	13	5	17
8	30	7	23	8	27	3	10	12	40	14	67	0	0
9	21	13	62	0	0	6	29	2	10	6	20	9	30
10	21	11	52	0	0	8	38	2	10	16	76	0	0
Mean	26.4	9.7	38.6	5.4	18.3	5.6	22.6	5.7	20.8	11.3	49.1	3.4	11.5
												6.4	25.2
												3.8	14.5

and the Communication condition continued into the work on the post-experimental exercise.

The prediction accuracy data show that the Non-Communication groups were somewhat superior both in terms of over-all correctness of prediction (61 percent as compared with 57 percent) and especially in terms of predicting an effective move (74 percent as compared with 61 percent). The Communication groups did less well in their analysis of the task, if this can be considered to be indicated by their prediction of effective moves. There is a slight suggestion in the data concerning correct prediction of ineffective moves (18.3 percent for the Communication groups as compared with 11.5 percent for the Non-Communication groups) that communication may have alerted these group members to consistencies in the moves to be expected of their partners which were not based on effectiveness of the moves. But the Communication groups were also more likely to make incorrect predictions of ineffective moves (20.8 percent as compared with 14.5 percent). It appears likely that this slightly larger frequency of expecting moves to be made that were not effective ones, (regardless of whether the prediction was correct) may be best understood as a reflection of a general failure to have analyzed the task correctly.

Discussion of the Results

The major result of this study shows that the 10 groups who were permitted to communicate did not perform their tasks more effectively than the 10 groups who were not permitted to communicate. This result was not anticipated. There are three general ways of accounting for such an unanticipated result. First, the sample of groups was very small, and it might be possible that with a larger sample the expected result would have been obtained.

Second, the groups' tasks, the manner of communication, or some other variable in the experimental situation may have operated to overcome the anticipated positive effect of communication. Third, the expected result was not a reasonable one to be expected, and the general hypothesis which prompted the study should be rejected. The first and third explanations appear less acceptable than the second. It is not likely the small sample size could account for results that were not only unexpected, but which tended to be statistically significant in the unanticipated direction. Furthermore, observations of the contents of the messages and of the post-experimental predictions all support the conclusion that the Communication groups performed the tasks less effectively.

The hypothesis that communication assists the development of structure-in-interaction and thereby increases effectiveness of task performance perhaps is a much too general statement. The relationship it describes may be correct within certain groups faced with certain types of tasks. The results of the present study do not suggest rejecting the experimental hypothesis and replacing it with the opposite; instead they suggest a need for specifying in what situation or under what circumstances a particular type of communication contributes to group effectiveness. The findings of the study suggest factors which tend to mitigate the utility of communication in group problem solving.

Task characteristics which produce requirements for analysis of specific details (i.e., careful individual thought) may be one of the factors involved. The two tasks of this experiment presented problems that were not to be solved by the most obvious routes. Consideration had to be given to the effect of a contemplated move upon the subsequent moves to be made by

others. Although it was well within the capabilities of each subject to determine the exact sequences of moves by which the group could reach the goal, such a determination required careful thought and detailed analysis. It seems reasonable to suggest that time and effort spent in communication activities would not be available for use in careful analysis of the task. Until the problem of how to reach the goal square had been solved by at least one member of a group communication could function only as a means of spreading confusion. In general, it is suggested that group tasks requiring individual concentration on technical details of the problem may be more effectively solved with some restriction or control on free communication.

The manner in which the group members are allowed to communicate may be a second source of factors related to whether the communication will add to the group's effectiveness. There is no evidence in the findings of the present experiment that points to the limit of 10 words per message as a factor influencing the result. No one appeared to be handicapped by this restriction; however, the arrangement of the plug boards did pose a communication problem. Some group members assumed that each person's board was oriented in the same manner as his own and that he could make use of such concepts as "up," "down," "right," or "left" in describing the locations of positions within the board. The use of such concepts was completely misleading to the recipient, as can be easily illustrated; for example, suppose that one subject wished to describe his own first move toward the goal and wrote to each of his associates the simple message, "I will make my first move to the right." Assuming that he did move as intended, one of his associates would see his move to the "left"; one "down"; and one "up."

A number of such confusing incidents were actually described and, in fact, one subject became visibly upset as a result of an interchange of messages with another who insisted upon the use of these "literal" concepts. Such problems of communication illustrate the importance of a common basic frame of reference if group members are to profit from communication in problem solving. Tasks in which such frames of reference are not available or are not applicable may be made more difficult by communication.

Summary and Conclusion

The performance on two tasks by 10 groups where the four members of each group were permitted to communicate by sending short messages between trials was compared with the performance of 10 groups whose members used a comparable amount of time to prepare a note to the experimenter about how the tasks might be solved. The Non-Communication groups appeared to perform the task in a superior manner; a result that was not anticipated. Detailed analysis suggests that certain task characteristics may have been responsible for the result and that under certain conditions group task performance is hindered rather than facilitated by communication. Such characteristics may include (a) requirements for detailed or technical analysis of the groups' task and (b) lack of a common frame of reference for interpretation of attempts to communicate.

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APPENDIX A

General Instructions

In all probability you are wondering just what it is we are going to do today. Briefly, we are trying to find out with your help and cooperation just how members of a group work together to solve a common task. We shall be here at least two to three hours, so please make yourselves comfortable. You may smoke if you wish. Because of the nature of the experiment, we must place two restrictions upon you. First, we must ask that you do not leave your cubicles and, second, that you do not speak to the other members of the group from the time the question periods are over until the experiment has ended.

Each of you is now seated in front of a red and black board that has been divided into 25 numbered and lettered squares. As you have seen in your preliminary tour of the lab there are four such boards, one for each of you. These boards are all electrically interconnected in such a way that you may follow the progress and the decisions of the other three members of your group.

Before I go on to describe to you just what it is that we wish you to do with these boards in front of you, it is necessary that we familiarize you with their operation. First, each of you will notice that at the bottom of the board in front of you there is a long strip of colored tape. The color of that strip of tape is your color. When or if it becomes necessary to communicate with one of you, your specific color will be used as a convenient name. In front of the board lying on the table, you will see four different colored phone plugs. Pick up the colored plug that corresponds to your color. If you examine this plug you will note that it alone has a red top--the other three have black tops. In the experiment in which you will be participating, you will be moving about to the different squares of the board in front of you. This plug that corresponds to your color, the one with the red top, represents

you, your movements, and your decisions. The other three colored plugs, the ones with black tops, represent the other three members of your group and their movements. We shall call them "marker plugs," and you will use them to keep track of the positions of the other members of the group.

Now, will the person who holds the Blue plug with the red top please place it in the socket in square A4. It should be noted that it is not necessary to push these plugs all the way into the socket. You will find it much easier and much more convenient to insert them only as far as necessary to turn on the lights. Now you will all note that a light has come on above the socket in square A4. Only the plug with the red top, the one that represents one individual's movements, is capable of lighting up the board. You know then that someone in the group has made a move, and in this case it was Blue. The rest of you should pick up your Blue marker plugs and place them in square A4.

Now, will Green place his red-topped Green plug in square B4. The rest of you will note that a light has come on in square B4. You know that Green has moved to B4, so place your Green marker plugs in B4 to indicate on your board that Green now occupies square B4.

Will Yellow please place his red-topped Yellow plug in square B5. B5 is now lit. Place your Yellow marker plugs in square B5.

Finally, will White place his red-topped White plug in square A5. A5 is now lit. Place your White marker plugs in square A5.

As mentioned before, only the red-topped plugs are capable of lighting the board; the black-topped plugs, or marker plugs, cannot light the boards. You may verify this fact by taking any black-topped plug and inserting it anywhere in the board. You will notice that it does not cause a light to come on. Now please return your marker plug to its previous position.

Are there any questions about the operation of the board?

Directions for Task I

We have already stated that we wish to find out how members of a group work to solve a common problem. Now we shall try to explain just exactly what that problem is and what rules you must follow as you work to solve it. Stated briefly, the problem is for you as a group to get any member of your group as represented by a plug on the board into square E1 in as few moves as possible. At first glance this task would appear easy and would be easy except for the rules that we have imposed. You will find a copy of the rules lying to the right of your plug boards. Perhaps you would like to read them silently as I read them aloud. If there is any doubt as to their meaning, please feel free to ask questions as soon as I have finished. Here are the rules with a bit of explanation.

1. You must move in turn according to color in the following order: Blue, Green, Yellow, and White. You will notice the shorter strips of colored tape around the edge of your boards. Starting with Blue and going clockwise the colors are Blue, Green, Yellow, and White. This is the general order in which you will move. However, Blue will not necessarily always go first. You will also note towards the top of your board a strip of white tape on which this order has been written. Above each color there is a light. These lights will come on one at a time to indicate just whose move it is. For example, should the light above Blue come on, it is Blue's move. These lights may be used by all of you as a handy reference as to whose move it is at present and how soon you yourself will be required to move. You as individuals will be allowed to move only when the light above your color is on.

2. You must make your move within 20 seconds after your turn has begun. Each of you will have 20 seconds after the beginning of your turn to decide

where you are going to move. At the beginning of each trial and thereafter between each turn, we shall turn out the lights on the boards for a few seconds. When you see the lights come on again, if it is your turn you will know that your 20-second turn has begun. Only one person should move during any 20-second interval. As soon as the lights come on, the person whose turn it is should remove his red-topped plug from the board and replace it in its new position. The other members should then move the same colored marker plugs to this new position on their individual boards. Should the lights go off signaling the end of the turn before any move is made, the mover will forfeit his turn and return his plug to its old position.

3. You may move to any unlit square on the board no matter how many squares away it may be or in what direction it may lie, or you may elect to remain in your present position. The only limitation is that you move in such a way as to maintain all four plugs in adjacent squares. You may move your plug to any unlit square on the board in any direction: backwards, forwards, to either side, or diagonally. You may move any number of squares you wish. You may jump over another plug. Or, you may elect to remain in your old position. You may signal this decision to the other members of your group by replacing your plug in its old position. The only limitation to your movement is this--you must always move so as to keep all four plugs in adjacent squares. That is, the lights or the plugs must always be kept together without unlit squares between them. They may be adjacent or next to one another, either above or below, to either side, or on the diagonal, but there cannot be an unlit square between any one or more plugs. Nor may you move in such a way as to cause another member of the group to become non-adjacent. For example, if White were between Green and the rest of the group, White could not move in such a way as to leave Green with one unoccupied or unlit square between him and the group.

Are there any questions concerning the rules?

The experiment to follow is divided into a number of trials. Each trial will end in one of two different ways. A trial shall be considered ended when you as a group succeed in lighting square E1 or when the group has moved seven times. That is to say, you must succeed in lighting square E1 in seven moves or the trial shall end in failure, and we shall move on to the next one. The goal may be reached in as few as five moves, and you should try to discover as quickly as possible a way in which this may be done. At the end of any trial in which you succeed in lighting square E1 before you have used your seven moves you will be told how many moves it has taken you to reach the goal. I remind you again that this task may be solved in five moves and that you should try to discover how this may be done as soon as possible.

Demonstration Trial. In case any of the instructions are still unclear we shall go through a short demonstration trial. We hope that this demonstration will serve to acquaint you with all of the different possibilities for the movement of your individual plugs and will demonstrate to you the concept of adjacency or keeping together as it applies within the framework of this task.

For purposes of this demonstration please place your plugs in the following squares: Blue in B2, Green in C3, Yellow in D3, and White in E4. Now to show you the flexibility with which your plugs may move, let us say that it is Blue's move. There are 10 different squares to which Blue might move. He could move to B3, B4, D4, (C4), D5, E5, E3, E2, (D2), and C2 or he could elect to remain in B2.¹ He may move to any square anywhere about the entire

¹Due to an error in the instructions, the squares C4 and D2 were omitted in list. No subjects have noted the error, however.

circumference of the group, provided that the square to which he elects to move is adjacent or next to one of the squares occupied by another member of the group.

You will notice that Blue is not limited by the distance or direction of his movement. His only consideration was that he maintain all four plugs in adjacent squares; that is, together without unlit squares between them.

Now let us look at the possibilities that exist for Green. Because of Green's central location in the group, you will see that the possibilities for his movement are much more limited if he is to follow the rules. Because he cannot move in such a manner as to isolate Blue, only two possibilities exist: the first, that he remain in his present position; or the second, that he move to square C2 which would still satisfy the rules of adjacency.

Specific instructions for communication groups. To help you in this task, you will be allowed to send a short message of 10 words or less to as many of the other members of the group as you wish; that is, up to three separate messages. You will have one minute at the end of each trial to write your messages, at which time they will be collected and delivered to the person or persons to whom they are addressed. The person to whom a message is addressed will have one minute to read the message before it is collected again. You should address your message to the color denoting the person to whom you wish to communicate and sign it with your own color. There is no limitation as to contents, but remember you must make your message 10 words or less. You do not have to send a message, but you will lose nothing if you do so.

Specific instructions for non-communication groups. To help you in this task, you will be allowed a period of one minute at the end of each trial to

examine the problem. At the end of this time you will be required to write a short note to me. If you have discovered the answer, you should jot down the five moves required for the solution of the task. If you have not as yet discovered the solution, write "no solution" on your note and pass this in. Each of you will be required to pass me a note at the end of each trial. Each of you should sign these notes with your color.

Reminders given between trials in Task I. As appropriate:

1. That time it took you _____ moves to reach the goal E1. Remember that E1 may be reached in as few as five moves and you should try to discover how this may be done as quickly as possible.

2. Seven moves have elapsed and you have not reached the goal E1. Remember that E1 may be reached in as few as five moves and you should try to discover how this may be done as quickly as possible.

Directions for Task II

Now we shall start a second task. With one exception the general rules of this new task will be the same as those used in the first task. You will still be trying to reach the goal square E1 in as few moves as possible, and you will still be able to move your individual plugs about the board exactly as you have done before. The rule that we have changed has to do with the way in which you must keep together.

By now all of you should be fairly familiar with the rules of adjacency, or keeping together, as they were applied in the first task. Previously, it could be said that you became legally adjacent to another member of the group when you placed your plug in any square that bordered an already occupied square, either on one of its four sides or on one of its four corners. In other words, if the unlit square to which you desired to move touched an occupied square at any point, either on one of its sides or on one of its corners, you could legally move there and be considered adjacent. If you think about it a minute you will see that a single square may have as many as eight other squares adjacent or next to it. This is the same as saying that you have a choice of eight different squares into which you might move your plug if you wish to become adjacent to that particular square.

Now these eight squares may be divided into two kinds with respect to the kind of adjacency they have with a single square. Let us take for example C3. Let us say that C3 is occupied and that you are trying to get another plug next to it. There are four separate squares that border directly on the sides of square C3, that is to say, on its top, its bottom, and its right and left edges. These are squares B3, C2, D3, and C4. If you should move to any one of these four squares we will say that a "side

connection" has been formed with C3. In addition to these four squares there are four other squares that border on square C3 though they do so only at its corners. These are B2, D2, D4, and B4. If you should move to one of these four squares we will say that a "corner connection" has been formed with C3. All of these moves were legal and valid for forming connections with and among the group in the last task.

In this task only side connections, that is, connections directly to the top, bottom, and right and left sides of the square shall be considered legal or valid. Corner connections by themselves will no longer count as connecting you to the rest of the group or as connecting the group together. Corner connections will still occur as you move about the board, but they will never count as connections in themselves in this second task. There must then always be a side connection between each of you at all times. You will see then that you must always move to form a side connection and that you may never move in such a way as to leave another member of the group by himself or with only a corner connection between him and the group. In this second task a corner connection is the same as no connection at all.

Are there any questions?

Instructions given between trials in Task II. You should spend the next one and one-half minutes studying your boards and attempting to discover how all problems of this nature may be solved in a minimum number of moves.

Communication groups:

You have one minute, beginning now, to write messages to the rest of the group, if you wish to do so.

Non-Communication groups:

You have one and one-half minutes, beginning now, to study the problem to try to find its solution.